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PROGRESS REPORT ON WOOD-PAVING EXPERIMENTS IN MINNEAPOLIS.

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PROGRESS REPORT ON WOOD-PAVING EXPERIMENTS IN MINNEAPOLIS.

INTRODUCTION.

This circular gives the results obtained after four years of heavy traffic in a service test on wood paving blocks of various species laid in cooperation with the city of Minneapolis, Minn.

Acknowledgment for assistance rendered in this experiment is due especially to the city engineer department of the city of Minneapolis; the Republic Creosoting Co. and the Kettle River Co. (formerly the Kettle River Quarries Co.), both of Minneapolis; the John Week Lumber Co., of Stevens Point, Wis.; the Cloquet Lumber Co., Cloquet, Minn.; the Larson Lumber Co., of Bellingham, Wash.; and the Westside Lumber & Shingle Co., Portland, Oreg.

DESCRIPTION OF THE TEST.

The experimental pavement is described in Forest Service Circular 141,[1] as follows:

THE EXPERIMENTAL PAVEMENT.

To learn the results of actual service on a larger number of woods than the manufacturers seemed likely to try under the existing public prejudice against unproved woods, the Forest Service undertook arrangements for the laying of an experimental pavement, in which some of the untried woods should be laid with those already standard.

* * * * * * *

VARIABLES.

The variables in this experiment, by means of which it was desired to gain information upon the points respectively involved, were:

(1) Species of wood.
(2) Heartwood and sapwood.
(3) Length of blocks.
(4) Angle of courses.

SPECIES OF WOOD.

The woods used in the experiment were longleaf pine, Norway pine, tamarack, Douglas fir, western larch, white birch, and hemlock. The longleaf pine was included in order to provide a standard of comparison by which the behavior of the other woods could be judged, since it is the species most used in the United States. It was the purpose to lay equal amounts, approximately 15,000 feet b. m., of each wood, or, allowing for ordinary waste in manufacture, about 65 linear feet of pavement on a street 50 feet wide. Various circumstances, particularly a lack of knowledge on the part of some of the lumber companies of the peculiar requirements for paving stock, largely increased the waste in sawing the blocks and prevented the full area being laid with some of the woods. The shortage in these woods was made up by others of which larger amounts were obtainable. The distribution of the species, as laid, is shown in figure 3. [See fig. 1, this circular.]

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[1] Wood Paving in the United States, by C. L. Hill.

HEARTWOOD VERSUS SAPWOOD.

The character of the blocks of the different woods used was as follows:

Approximately all heart: Longleaf pine, Douglas fir, and western larch.

Mixed heart and sap: Norway pine and tamarack.

Heartwood and sapwood indistinguishable: White birch and hemlock.

It was unnecessary to make separate classes for this condition within the separate species, since any difference in resistance between heartwood and sapwood would become manifest in an uneven wearing of the blocks, rather than in a greater total wear. Therefore this variable would not obscure the results affecting the separate species.

LENGTH OF BLOCKS.

The lengths of the blocks in the different species are as follows:

	Inches.
Longleaf pine, variable	6 to 10
Norway pine, variable	6 to 10
Tamarack, variable	6 to 10
Douglas fir, variable	6 to 10
Hemlock	6
Western larch, one-half	4
Western larch, one-half	6 and 8
White birch, one-half	4
White birch, one-half	6 and 8

The width and also the depth of all the blocks was 4 inches. The larch, birch, and hemlock were air-seasoned for several months before being used. Exact records of the time of seasoning of the other woods were not obtainable, but none of them were entirely green when used. Of the Douglas fir, a portion was from very rapidly grown stock, and it was feared that it would be so weak that it would not fairly represent the average of this timber. Therefore further separation on the basis of this factor was made for this wood, and the narrow-ringed and wide-ringed blocks were laid in separate portions of the pavement.

* * * * * * *

CONSTRUCTION OF THE PAVEMENT.

Nicollet Avenue, on which this pavement is laid, is 50 feet wide. There is practically no gradient. The street was so prepared as to give to the pavement a crown of 8 inches. The foundation was made of Portland cement concrete, composed of Portland cement, 1 part; sand, 3 parts; crushed limestone, 7 pars; and was 5 inches in thickness. Over this as soon as it was sufficiently set was spread a 1-inch cushion of sand. The surface of the sand was carefully trued to grade, and upon this foundation the blocks were laid, as shown in figure 3. [See fig. 1, this circular.]

The area of the avenue between Washington Street and Second Street was reserved for the several species to be compared, and these were laid all at the same angle, 67½° with the curb. North of Second Street one wood, Norway pine only, was laid, and on this area different angles were used for the courses, one portion being laid at 90° to the curb, another at 45°, and a third at 67½°. The relation of these areas will be seen from the figure.

The body of the pavement was laid with close joints, the pavement being driven moderately after every dozen or so courses. At each curb was left a 1-inch expansion joint, between which and the body of the pavement was one longitudinal course of blocks. As soon as the pavement was laid it was thoroughly rolled with a steam roller. The expansion joints, which had been left open until the pavement should be rolled and thoroughly settled, were then filled with sand nearly to the top. The body joints and the top of the expansion joints were filled with pitch, heated to about 300° F., which was thoroughly broomed in with steel brooms. A light top dressing of sharp sand completed the pavement. As soon as thorough setting of the concrete was assured traffic was admitted.

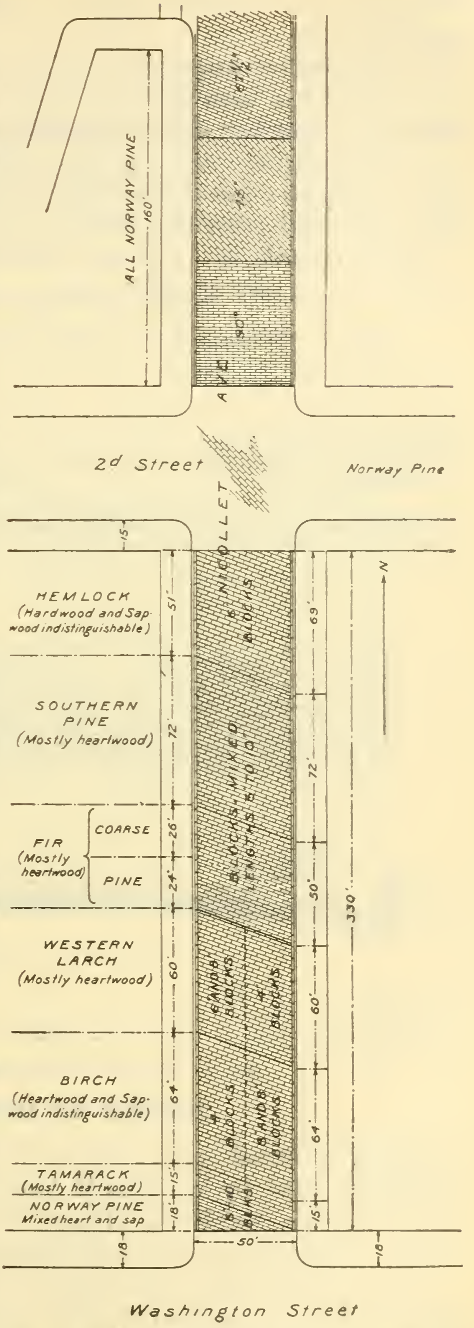
ALL NORWAY PINE
160'
67½'
45'
90'
AVE
NICOLLET
2d Street
Norway Pine
15'
HEMLOCK (Hardwood and Sapwood indistinguishable)
51'
69'
N
SOUTHERN PINE (Mostly heartwood)
72'
72'
6" BLOCKS
BLOCKS, MIXED LENGTHS 6" TO 10"
FIR (Mostly heartwood)
COARSE
26'
PINE
24'
50'
330'
WESTERN LARCH (Mostly heartwood)
60'
60'
6" AND 8" BLOCKS
4" BLOCKS
BIRCH (Heartwood and Sapwood indistinguishable)
64'
64'
4" BLOCKS
6" AND 8" BLOCKS
TAMARACK (Mostly heartwood)
15'
NORWAY PINE Mixed heart and sap
18'
15'
50'
18'
18'
Washington Street

FIG. 1.—Experimental Creosoted Wood Block Pavement, Minneapolis, Minn.

The blocks were treated at the plants of the two creosoting companies cooperating in the experiment under the specifications of the city of Minneapolis for wood block pavement which were in force during 1906.[1] In brief, these specifications require that wood blocks be treated by a straight-pressure treatment with 16 pounds per cubic foot of a coal-tar oil having a specific gravity of 1.09 at 20° C. However, the oil used in the treatment of the white birch and western larch blocks had a lower specific gravity than that specified. An impregnation of 20 pounds per cubic foot was therefore used in the case of these species in order to compensate as nearly as possible for the discrepancy in specific gravity between the oil used and that specified.

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[1] The specifications for paving oil of the city of Minneapolis for 1906, analyses of the oils actually used in the treatment of the experimental blocks, and records of the treatment are given on pages 12 and 13 of the Appendix.

At the time of inspection the city engineer department reported that since it had been laid the test pavement had been sprinkled with water six times per day during the sprinkling season and machine-swept each night. The department also reported that it was necessary to remove a few of the birch blocks which had failed from rotted heart, but that otherwise there had been no replacements.

Travel records of 12 hours' duration each were taken twice a month, a summary of which is given in Table 1.

TABLE 1.—*Summary of travel records taken on the experimental pavement.*

	1906	1907	1908	1909	1910
Average tons per foot of roadway	127.17	132.02	149.15	143.52	154.23
Estimated 90 per cent of travel on middle 25 feet of roadway, average tons per foot.[1]	228.94	237.65	268.46	258.50	278.00

[1] Detailed travel records for 1906 and detailed summaries of travel records for succeeding years are given on pages 16-19 (includes Tables 6-10) of the Appendix.

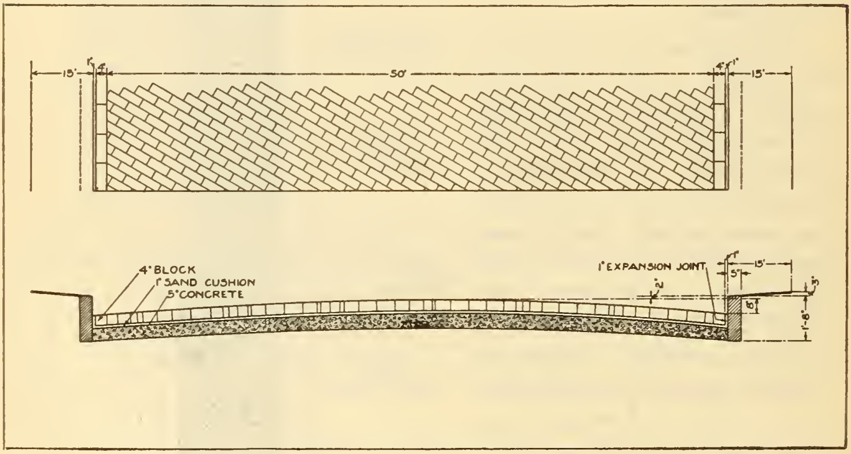

FIG. 2.- Construction of the experimental pavement.

METHOD OF INSPECTION.

The first formal inspection of the test pavement was made on August 17, 1910, by Mr. Ellis R. Dutton, assistant city engineer, city of Minneapolis, Mr. Frank Hussey, of the Kettle River Co., and the writer. The following observations were made:

(1) In each section one block of apparently average wear was removed from a position midway between the curb and the center of the street and a second block from near the curb. The two blocks were measured, and the difference in their heights was taken as the average wear of the section in question, the assumption being that

the blocks near the curb were not appreciably worn.[1] It was not thought best at the time of the inspection to remove a greater number of blocks from the general level of the sections. However, some additional blocks were removed from depressions.

(2) In order to obtain the approximate areas of holes in the pavement, each member of the party carefully estimated the total number of square feet of depression below the general surface in each section of the pavement. The estimates were averaged for each section, and these averages were taken as the areas of the depressions of the sections.

RESULTS OF INSPECTION.

Results of the inspection are given in Table 2. Since only two sections of the pavement were in a bad condition, no general conclusion can be drawn. However, a number of interesting points were observed, and the results of the inspection enable a tentative comparison of species to be made.

TABLE 2.—*Results of the first inspection of experimental pavement laid in Minneapolis, Minn., in 1906.*

Section No.	Species.	Area of section.	Original depth of block.	Depth of block of average wear for section.	Average wear of section.[1]	Area local depression one-half inch and less below general level of section.	Area local depression one-half inch and less below general level of section in per cent of total area of section.	Area local depression 3 inches to one-half inch below general level of section in per cent of total area of section.	Remarks.
		Sq. ft.	*Inches.*	*Inches.*	*Inches.*	*Sq. ft.*	*P. ct.*	*P. ct.*	
1	Norway pine.......	440	$3\frac{15}{16}$	$3\frac{3}{4}$	$\frac{3}{16}$	10	2.0	....	All apparent depressions in one spot, possibly due to fire.
2	Tamarack..........	742	$3\frac{15}{16}$	$3\frac{3}{4}$	$\frac{3}{16}$	10	1.0	....	
3	White birch (6 and 8 inch blocks)	1,609	$3\frac{13}{16}$	$3\frac{5}{8}$	$\frac{3}{16}$	8	.5	....	About 40 to 50 blocks removed on account of decayed heart.
4	White birch (4-inch blocks).	1,615	$3\frac{13}{16}$	$3\frac{5}{8}$	$\frac{3}{16}$	10	.5	....	Some blocks showed decayed heart.
5	Western larch (4-inch blocks).	1,505	$3\frac{13}{16}$	$3\frac{1}{2}$	$\frac{5}{16}$	33	2.0	....	
6	Western larch (6 and 8 inch blocks).	1,497	$3\frac{13}{16}$	$3\frac{7}{16}$	$\frac{3}{8}$	55	3.5	....	
7	Douglas fir.........	1,229	$3\frac{15}{16}$	$2\frac{7}{8}$	$1\frac{1}{16}$	....	30.0	35.0	Medium grain, 6 to 7 rings per inch.
8	.....do..............	1,293	$3\frac{15}{16}$	$2\frac{7}{8}$	$1\frac{1}{16}$	....	30.0	3.0	Coarse grain, 3 to 5 rings per inch.
9	Long leaf pine......	3,583	$3\frac{15}{16}$	$3\frac{7}{8}$	$\frac{1}{8}$	17	.5	....	
10	Eastern hemlock...	3,038	$3\frac{15}{16}$	$3\frac{3}{4}$	$\frac{3}{16}$	35	1.0	....	

[1] Exclusive of local depressions below the general level of the section.

Sections 7 and 8 (coarse and medium grain Douglas fir) were so badly worn that the blocks had to be removed during the following summer. The extreme depth of some of the depressions in the Douglas fir sections of the pavement requires some explanation, however, since the depth of depression does not in this case necessarily indicate the actual wear. Upon removal of several blocks from the lowest depressions it was found that the grain of the wood was no longer vertical but was inclined at a considerable angle, the blocks being separated into a number of pieces by longitudinal shear along the annual rings. This shearing and consequent inclination of the blocks must have taken place after the blocks had once become so reduced in depth by wear that their shearing strength could no longer resist the local tractive action to which they were subjected. The continual lessening of lateral support to the wood effected by wear and the continually increasing angle of inclination, of course, accelerated this action. The result is clearly shown in figure 3.

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[1] Table 2 shows that the white birch and western larch blocks manufactured at Sandstone, Minn., had a depth of $3\frac{13}{16}$ inches, and that the blocks of other species manufactured in Minneapolis, were $3\frac{15}{16}$ inches in depth. While no records of the exact original depth of the blocks are available, it is recalled that the one lot of blocks was of slightly less depth than the other.

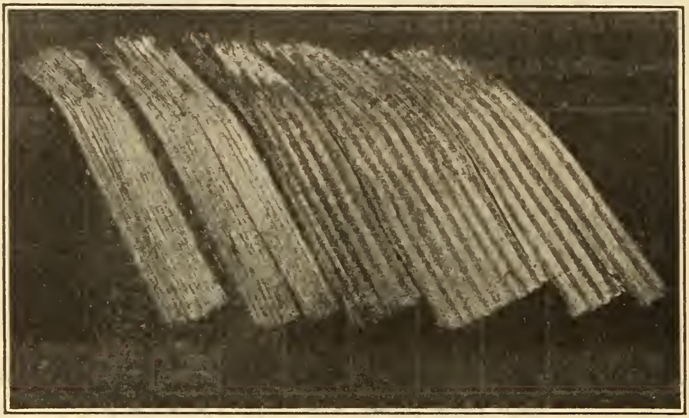

FIG. 3.—Badly worn Douglas fir paving block removed from a deep depression in the test pavement.

Since the Douglas fir was of rapid growth and poor grade, it is questionable whether the results of this test are a fair indication of its wearing qualities when used as a paving material.

Table 2 shows that the other blocks appear to have worn fairly uniformly. Sections 5 and 6 (western larch) show a greater average wear and also a larger percentage area of depression below the general level than the others. Section 9 (longleaf pine) shows the least average wear, and also presents a very uniform surface. Section 1 (Norway pine), section 2 (tamarack), and section 10 (eastern hemlock) showed equal average durability up to the time of the first inspection, and were only slightly below the longleaf pine; however, they showed a somewhat larger percentage of holes than the longleaf pine. The white birch, while showing little more wear and no more holes than the longleaf pine, had some replacement on account of heart rot. Since the Norway pine had all of its apparent depression below the general level in one spot, it seems unlikely that this was caused by ordinary wear. On this account, also on account of the small area of the Norway pine section,[1] and because the rest of the section was very uniform, it is hardly fair to give percentage area of depression below the general level any weight in this case.

Until further results have been obtained from the test pavement, the species used may be tentatively grouped in accordance with the results of this inspection in the order of their value for creosoted paving material as follows:

1. Longleaf pine.
2. Norway pine, white birch, tamarack, eastern hemlock.
3. Western larch.
4. Douglas fir.

No more definite comparison of the species can be made until the blocks have remained in the pavement long enough to exhibit greater differences in wear.

At the time of the inspection the pavement was not examined for differences in wear due to mixed sapwood and heartwood, length of blocks, or angle of courses. However, at a later date an examination was made with these points in view, but no appreciable differences due to any of these variables were noted.

RELAYING THE ORIGINAL DOUGLAS FIR SECTIONS.

At the beginning of the summer of 1911, nearly five years after the laying of the test pavement, the Douglas fir blocks were in such bad condition that it was necessary to remove them from the street and relay this portion of the pavement. Figure 4 shows the general condition along the central portion of the street just before the relaying of the Douglas fir sections. In one spot, comprising an area of about 30 square feet (not shown in the figure), the blocks were so badly worn that they were completely shattered into small bits.

In view of the poor quality of the original Douglas fir blocks, it was decided further to test this species by relaying one of the worn-out sections of the pavement with a thoroughly good grade of Douglas fir. Accordingly, a quantity of grade A Douglas fir paving stock was procured for this purpose. It was the intention to replace the second worn-out section with a good grade of jack pine, but so much difficulty was encountered in procuring the timber that the plan was abandoned. Douglas fir blocks were laid over as much of the area to be repaved as the quantity secured would cover, and the remaining part was paved with the regular southern yellow-pine blocks then in use by the city and furnished by it.[2] The Douglas fir was furnished by the Westside Lumber & Shingle Co., of Portland, Oreg., and was manufactured into blocks and treated by the Republic Creosoting Co., of Minneapolis. The arrangement of the relaid sections, together with the original sections which were still in good condition at the time of the relaying, is shown in figure 3.

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[1] The Norway pine blocks laid for testing the angles of the courses are not considered in this comparison.

[2] The actual manufacture and treatment was done by the Republic Creosoting Co., but not, as in the case of the Douglas fir, without charge.

Both the Douglas fir and the southern yellow-pine blocks were practically all heartwood, straight grained, and of fairly uniform growth; the minimum average number of annual rings for any single block being 9 for the Douglas fir and 6 for the southern yellow pine. The depth of the blocks of both species was $3\frac{15}{16}$ inches and the width approximately 4 inches. However, the Douglas fir blocks were all 8 inches in length, while the southern yellow-pine blocks varied in length from 5 to 10 inches, with an average length of 8 inches. The Douglas fir paving stock was seasoned approximately two months, and the southern yellow pine one month, before being manufactured into blocks. The latter operation preceded the treatment by only a few hours in each case.

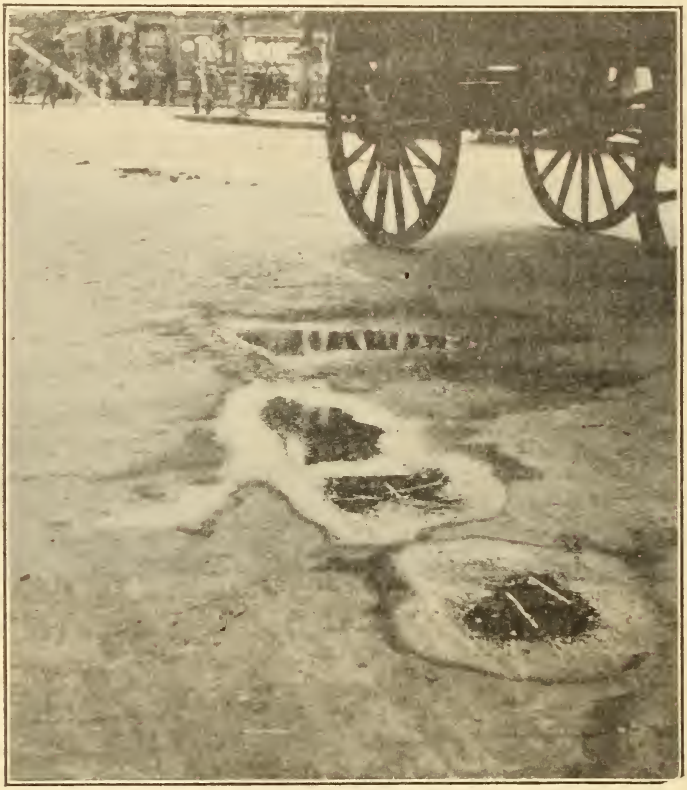

FIG. 4.—General condition along the central portion of the street of the original Douglas fir blocks in the test pavement after 5 years' service.

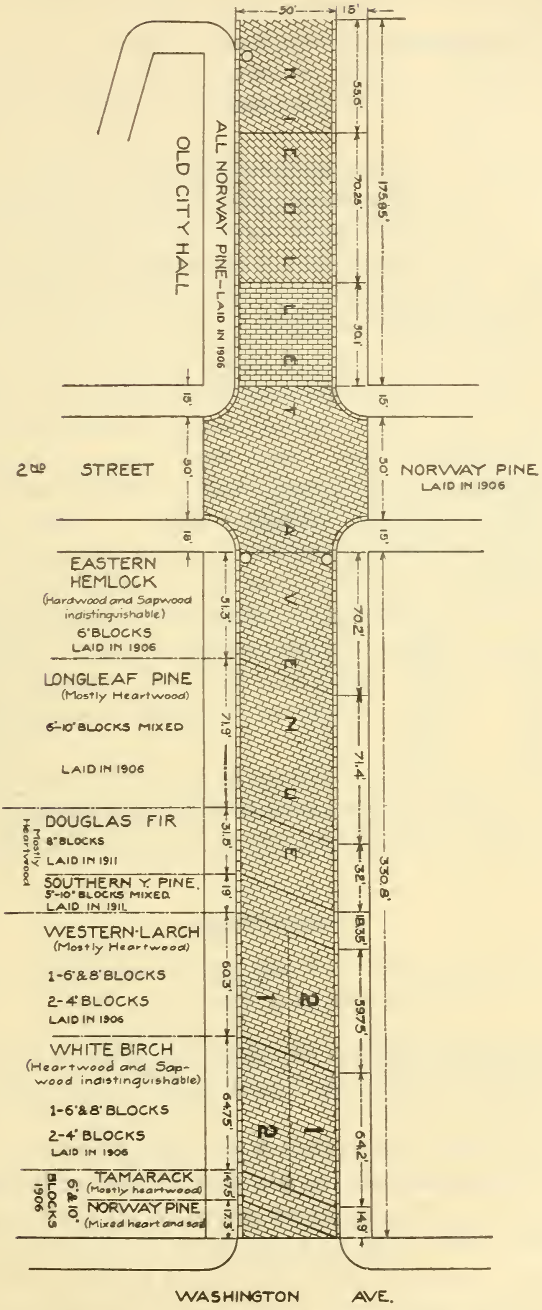

FIG. 5.—Arrangement of the experimental pavement laid in the summer of 1906; partially relaid June 27, 1911.

The blocks were treated at the Minneapolis plant of the Republic Creosoting Co. in two separate runs.[1] The Douglas fir blocks were treated with 17.9 pounds of creosote paving oil per cubic foot of wood; the specific gravity of this oil being 1.108 at 38° C. The southern yellow-pine blocks were treated with 17.3 pounds of a similar oil per cubic foot of wood.

The relaying of the pavement began June 27, 1911. It was noted that the old blocks from the middle of the pavement were so badly shattered that they fell apart into small chips as they were being taken up, although the blocks from near the curb came out practically whole. The sand cushion and the foundation were found to be in apparently perfect condition.

The foundation was scraped clean of the original sand cushion, and fresh, clean, practically gravel-free sand was spread over its surface. This new sand cushion was then surfaced off by a long metal-shod "straight-edge" which was drawn across the street, its two ends resting on 1-inch boards which were laid across the foundation and which served as "distance strips." This operation left a cushion of sand on the foundation 1 inch in thickness, the surface of which was further prepared by the use of a small hand scraper. The new blocks were then laid in the same manner as the original blocks, except that the former were driven only enough to keep the courses straight, and that the hot pitch filler was brushed into the body joints with a wooden scraper or "squeege" instead of with steel brooms.

The test pavement will continue to be under observation and care, and traffic records will be taken in the same manner as heretofore. Inspections will be made whenever they seem advisable.

APPENDIX.

SPECIFICATIONS OF THE CITY OF MINNEAPOLIS FOR WOOD-PAVING-BLOCK OIL FOR THE YEAR 1906.[2]

The specific gravity of the oil, at 20° C., shall be at least 1.09.

The oil shall be completely liquid at 25° C., and show no deposit on cooling to 22° C.

It shall not contain more than 2 per cent of water nor more than 3 per cent of matter insoluble in absolute alcohol or benzene.

Distillation test: One hundred grams of oil shall be placed in an 8-ounce retort, fitted with a thermometer, the bottom of whose bulb shall be placed one-half inch above the oil and not moved during the test. The discharge opening of the retort shall be from 20 to 24 inches from the bulb of the thermometer, and the retort shall be covered to prevent too rapid radiation. The percentages are for dry oil, and by weight:

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[1] The specifications for paving oil of the city of Minneapolis, Minn., for 1911, the analyses of the oils used in the treatment of the experimental blocks, and records of the treatments are given on pages 13 and 14 of the Appendix.

[2] Reprinted from Forest Service Circular 141.

Up to 150° C., nothing must come off.
Up to 170° C., 2 per cent.
Up to 210° C., from 6 per cent to 8 per cent.
Up to 235° C., from 20 per cent to 30 per cent.
Up to 315° C., from 40 per cent to 50 per cent.
Up to 355° C., from 60 per cent to 80 per cent.

Distillation shall be gradual and be completed, up to 315° C., in 30 minutes from the first drop, and entirely completed in 40 minutes.

TABLE 3.—*Analyses of the oils used in 1906 in the treatment of the paving blocks laid in the original test pavement.*[1]

	Birch treated at Sandstone, Minn., July 3, 1906.	Larch treated at Sandstone, Minn., July 5, 1906.	All others treated at Minneapolis: Fir, July 18, 1906; southern pine, July 1, 1906; hemlock, July 9, 1906.	Minneapolis specifications.
Specific gravity of oil at 20° C	1.07	1.07	1.09	1.09
Liquid at 22° to 25° C	Solid.	Solid.	Liquid.	Liquid.
Water per cent	5.20	5.20	2.30	2.00
Loss per cent up to 150° C	.05	.10	.40	0
Loss per cent up to 170° C	.37	.40	1.35	0 to 2
Loss per cent up to 210° C	5.82	5.36	7.90	6 to 8
Loss per cent up to 235° C	46.56	45.70	27.50	20 to 30
Loss per cent up to 315° C	72.91	72.28	59.60	40 to 50
Loss per cent up to 355° C	83.01	81.21	74.00	60 to 80

[1] From Annual Report of City Engineer City of Minneapolis, 1906.

TABLE 4.—*Record of the treatment of the paving blocks laid in the test pavement in 1906.*[1]

Species.	Square yards.	Treatment.		Pounds of creosote per cubic foot.
		Place.	Creosoting Co.	
White birch	358	Sandstone, Minn	Kettle River Quarries Co.	22.1
Western larch	333	....do	....do	20.4
Douglas fir	280	Minneapolis, Minn	Republic Creosoting Co.	15.8
Eastern hemlock	338	....do	....do	15.5
Longleaf pine	398	....do	....do	18.5
Tamarack	335	....do	....do	16.2
Norway pine	4,213	....do	....do	16.0

[1] From Annual Report of City Engineer City of Minneapolis, 1906.

SPECIFICATIONS OF THE CITY OF MINNEAPOLIS FOR PAVING-BLOCK OIL FOR THE YEAR 1911.

The oil to be used in the treatment of the blocks shall be a pure heavy creosote oil, obtained from coal tar only, and of the following quality, viz:

The specific gravity of the oil shall be at least 1.10 at a temperature of 38° C.

It shall be completely liquid at 25° C. and show no deposit on cooling to 22° C.

It shall not contain more than 3 per cent of matter insoluble by hot continuous extraction with benzol and chloroform.

It shall be subjected to a distillation test, as specified below, and shall conform to the following requirements: 100 grams of oil shall be placed in an 8-ounce retort fitted with a thermometer, the bottom of the bulb of which shall be placed one-half inch above the oil and not moved during the test. The discharge opening of the retort shall be from 20 to 24 inches from the bulb of the thermometer and the retort shall be covered so as to prevent too rapid radiation. The percentages are for dry oil and by weight. The average of a number of tests shall show a mean of those percentages, viz, up to—

150° C., nothing must come off.
170° C., from 0 per cent to 0.5 per cent.
210° C., from 2 per cent to 4 per cent.
235° C., from 6 per cent to 16 per cent.
355° C., from 40 per cent to 55 per cent.

The distillation shall be gradual, and should be fully completed in 40 minutes from the first drop. Thermometer readings to be corrected for emergent stem.

TABLE 5.—*Analyses of the oils used in 1911 in the treatment of the paving blocks used in the relaid sections of the test pavement.*

	Oil used in treatments.	Minneapolis specifications.
Specific gravity of oil at 38° C	1. 108	1. 10
Liquid at 22° to 25° C	Liquid	Liquid.
Loss per cent up to 180° C	3. 4 (yellow oil and water)	0 to 0. 5 up to 170° C.
Loss per cent up to 210° C	15. 0 (yellow paste)	2 to 4
Loss per cent up to 235° C	30. 8 (yellowish white, solid)	6 to 16
Loss per cent up to 355° C	65. 2 (dark-brown oil)	40 to 55

Samples of oil were taken separately for the Douglas fir and southern yellow pine treatments. These were analysed by the Forest Service method and found to be identical; consequently only one analysis was made, using the retort as described in the Minneapolis specifications.

RECORD OF THE TREATMENT OF THE PAVING BLOCKS LAID IN THE TEST PAVEMENT IN 1911.

DOUGLAS FIR: REPUBLIC CREOSOTING CO., MINNEAPOLIS, JUNE 23, 1911.

Preliminary vacuum of 25 inches drawn in 24 minutes.

Oil admitted and pressure gradually applied for 50 minutes. Maximum pressure, 135 pounds per square inch. Temperature of cylinder during pressure period, 180° F. Temperature of measuring tank during pressure period, 200° F.

Absorption, as measured by the float gauge of measuring tank, 6 inches, or 1,176 gallons.

Specific gravity of oil at 210° F. (temperature at which preliminary and final gauge readings were taken), 1.065.

Amount of wood in treatment, 7,000 feet b. m. or 583 cubic feet.

Absorption, 17.9 pounds oil per cubic foot of wood.

SOUTHERN YELLOW PINE: REPUBLIC CREOSOTING CO., MINNEAPOLIS, JUNE 24, 1911.

Preliminary steaming at 150° F. for 1 hour 7 minutes.

Preliminary vacuum of 25 inches for 42 minutes.

Oil admitted and pressure gradually applied for 1 hour 16 minutes. Maximum pressure, 140 pounds per square inch. Temperature of cylinder during pressure period, 180° F. Temperature of measuring tank during pressure period, 200° F.

Absorption, as measured by the float gauge of measuring tank, 11¾ inches, or 2,303 gallons.

Specific gravity of oil at 210° F. (temperature at which preliminary and final gauge readings were taken), 1.065.

Amount of wood in treatment, 1,180 cubic feet.

Absorption, 17.3 pounds oil per cubic foot of wood.

TRAVEL RECORDS.

The following travel records are taken from the annual reports of the city engineer, city of Minneapolis, Minn., for the years 1906, 1907, 1908, 1909, and 1910. The complete detailed travel records are given here only for the year 1906, since that is sufficient to indicate the manner in which the records were taken. However, detailed averages for each succeeding year are given.

TABLE 6.—*Records of travel on Nicollet Avenue between Washington Avenue and Second Street during part of 1906.*

[Street paved in 1906 with 4-inch creosoted blocks on 5-inch Portland cement concrete foundation. Width of roadway, 50 feet. Records taken from 6 a. m. to 6 p. m.]

Classification of travel.	Wednesday, Aug. 1, 1906. Temperature: Maximum, 84; minimum, 63; weather, partly cloudy; moisture, none; condition of pavement, dry.		Thursday, Aug. 16, 1906. Temperature: Maximum, 93; minimum, 71; weather, cloudy; moisture, none; condition of pavement, dry.		Saturday, Sept. 1, 1906. Temperature: Maximum, 71; minimum, 57; weather, cloudy; moisture, 0.29; condition of pavement, wet.		Thursday, Sept. 20, 1906. Temperature: Maximum, 71; minimum, 61; weather, cloudy; moisture, 0.70; condition of pavement, wet.	
	Number.	Tons.	Number.	Tons.	Number.	Tons.	Number.	Tons.
Loaded:								
1-horse rubber tire	19	29.5	17	25.5	13	19.5	7	10.5
1-horse steel tire	266	399	286	429.	402	603	287	430.5
2-horse rubber tire	50	225	25	112.5	19	85.5	14	63
2-horse steel tire	528	2,376	572	2,574	592	2,664	548	2,466
4-horse steel tire	34	272	28	224	7	56	13	104
Light:								
1-horse rubber tire	294	294	221	221	248	248	209	209
1-horse steel tire	765	765	1,160	1,160	1,051	1,051	1,144	1,144
2-horse rubber tire	57	142.5	110	275	115	287.5	105	262.5
2-horse steel tire	334	835	461	1,152.5	407	1,017.5	467	1,167.5
4-horse steel tire	18	72	32	128	4	16	16	64
Horses	2	1.2	4	2.4	2	1.2	6	3.6
Bicycles	1,353	135.3	1,064	106.4	1,052	105.2	929	92.9
Automobiles	218	327	335	502.5	237	355.5	152	228
Total	3,938	5,873.5	4,315	6,912.8	4,149	6,509.9	3,897	6,245.5
Average tons per foot of roadway	....	117.47	....	138.26	....	130.16	....	124.91
Estimating 90 per cent of travel on middle 25 feet of roadway, average tons per foot	....	211.45	....	249.22	....	234.28	....	224.84
Teams trotting	1,618	....	2,038	....	1,980	....	1,912	....
Teams walking	747	....	874	....	878	....	898	....

Classification of travel.	Monday, Oct. 1, 1906. Temperature: Maximum, 70; minimum, 45; weather, clear; moisture, none; condition of pavement, dry.		Tuesday, Oct. 16, 1906. Temperature: Maximum, 74; minimum, 51; weather, clear; moisture, none; condition of pavement, dry.		Thursday, Nov. 1, 1906. Temperature: Maximum, 49; minimum, 32; weather, partly cloudy; moisture, none; condition of pavement, dry.		Tuesday, Nov. 16, 1906. Temperature: Maximum, 38; minimum, 32; weather, cloudy; moisture, 0.66; condition of pavement, wet.	
	Number.	Tons.	Number.	Tons.	Number.	Tons.	Number.	Tons.
Loaded:								
1-horse rubber tire	11	16.5	29	43.5	21	31.5	6	9
1-horse steel tire	485	727.5	570	855	276	414	353	529.5
2-horse rubber tire	10	45	81	364.5	63	283.5	38	171
2-horse steel tire	615	2,767.5	657	2,956.5	677	3,046.5	472	2,124
4-horse steel tire	27	216	40	320	31	248	11	88
Light:								
1-horse rubber tire	262	262	340	340	264	264	109	109
1-horse steel tire	966	966	821	821	1,165	1,165	656	656
2-horse rubber tire	73	182.5	88	220	192	480	90	225
2-horse steel tire	337	842.5	345	862.5	480	1,200	357	892.5
4-horse steel tire	27	108	36	144	21	84	2	8
Horses	5	3	2	1.2	....	....	5	3
Bicycles	1,234	123.4	1,153	115.3	749	74.9	31	3.1
Automobiles	248	372	247	370.5	172	258	61	91.5
Total	4,300	6,631.9	4,409	7,414	4,111	7,549.4	2,191	4,909.6
Average tons per foot of roadway	....	132.64	....	148.28	....	150.99	....	98.19
Estimating 90 per cent of travel on middle 25 feet of roadway, average tons per foot	....	238.75	....	266.90	....	271.77	....	176.75
Teams trotting	1,856	....	1,940	....	2,263	....	1,353	....
Teams walking	957	....	1,067	....	927	....	741	....

TABLE 6.—*Records of travel on Nicollet Avenue between Washington Avenue and Second Street during year 1906*—Continued.

Classification of travel.	Saturday, Dec. 1, 1906. Temperature: Maximum, 28; minimum, 6; weather, clear; moisture, none; condition of pavement, dry.		Wednesday, Dec. 19, 1906. Temperature: Maximum, 34; minimum, 21; weather, cloudy; moisture, trace; condition of pavement, dry.		Total average.	
	Number.	Tons.	Number.	Tons.	Number.	Tons.
Loaded:						
1 horse rubber tire	....	....	....	....	12.3	18.5
1-horse steel tire	236	354	362	543	352.3	528.4
2-horse rubber tire	1	4.5	2	9	30.3	136.4
2-horse steel tire	506	2,277	549	2,470.5	571.6	2,572.2
4-horse steel tire	12	96	11	88	21.4	171.2
Light:						
1-horse rubber tire	155	155	159	159	226.1	226.1
1-horse steel tire	1,015	1,015	897	897	964	964
2-horse rubber tire	119	297.5	88	220	103.7	259.3
2-horse steel tire	574	1,435	467	1,167.5	422.9	1,057.2
4-horse steel tire	8	32	12	48	17.6	70.4
Horses	....	....	2	1.2	2.8	1.7
Bicycles	208	20.8	81	8.1	785.4	78.5
Automobiles	76	114	85	127.5	183.1	274.7
Total	2,910	5,800.8	2,715	5,738.8	3,693.5	6,358.6
Average tons per foot of roadway	....	116.02	....	114.77	....	127.17
Estimating 90 per cent of travel on middle 25 feet of roadway, average tons per foot	....	208.83	....	206.60	....	228.94
Teams trotting	1,825	....	1,683	....	....	1,846.68
Teams walking	801	....	864	....	....	875.4

TABLE 7.—*Detailed average travel records on Nicollet Avenue between Washington Avenue and Second Street during 1907.*

Classification of travel.	Averages.				Total average for the year.[1]	
	For the first 3 observations when there was snow.		For the last 16 observations.			
	Number.	Tons.	Number.	Tons.	Number.	Tons.
Loaded:						
1-horse rubber tire	[2] 194.7	292	48.8	73.2	71.8	107.7
1-horse steel tire	[3] 146	219	543.8	815.7	481	721.5
2-horse rubber tire	[2] 327	1,471.5	50	225	93.7	421.8
2-horse steel tire	[3] 139	625.5	637.7	2,869.6	559	2,515.3
4-horse rubber tire	[2] 1.4	10.7	....	....	1.4	10.7
4-horse steel tire	[3] 2.4	18.7	29.5	236	25.2	201.7
Light:						
1-horse rubber tire	[2] 505	505	199.4	199.4	247.7	247.7
1-horse steel tire	[3] 117	117	799.9	799.9	692.1	692.1
2-horse rubber tire	[2] 263	657.5	73.1	182.8	103.1	257.8
2-horse steel tire	[3] 74	185	421.2	1,053	366.4	915.9
4-horse rubber tire	[2] 1	4	....	....	1	4
4-horse steel tire	[3] 2.4	9.3	17.7	70.8	15.3	61.1
Horses	6	3.6	9.9	5.9	9.3	5.5
Bicycles	5.7	.6	976.9	97.7	823.6	82.4
Automobiles	15.7	23.5	288.8	433.1	245.7	368.4
Total	1,800.3	4,142.9	4,096.7	7,062.1	3,736.3	6,613.6
Average tons per foot of roadway	....	82.86	....	141.24	....	132.02
Estimating 90 per cent of travel on middle 25 feet of roadway, average tons per foot	....	149.15	....	254.24	....	237.65
Teams trotting	1,538.7	....	1,775.6	....	1,738.2	....
Teams walking	234.2	....	1,045.5	....	917.4	....

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[1] This column did not appear in the city engineer report for 1907, but was added in order to make the summaries uniform.

[2] Sleds.

[3] Wagons.

TABLE 8.—*Detailed average travel records on Nicollet Avenue between Washington Avenue and Second Street during 1908.*

Classification of travel.	Averages.				Total average for the year.	
	For the first 2 observations when there was snow.		For the last 10 observations.			
	Number.	Tons.	Number.	Tons.	Number.	Tons.
Loaded:						
1-horse rubber tire	[1] 156	234	31	46.5	51.8	77.8
1-horse steel tire	[2] 265	397.5	432.7	649.1	404.7	607.2
2-horse rubber tire	[1] 127.5	573.7	45.2	203.4	58.9	265
2-horse steel tire	[2] 334.5	1,555.3	682.5	3,071.2	624.5	2,818.6
4-horse steel tire	[2] 2	16	28.6	228.8	24.1	193.4
Light:						
1-horse rubber tire	[1] 286	286	248	248	254.3	254.3
1-horse steel tire	[2] 409	409	1,005.4	1,005.4	906	906
2-horse rubber tire	[1] 130	325	125.9	314.8	126.6	316.5
2-horse steel tire	[2] 254	635	521.4	1,303.5	476.9	1,192.1
4-horse rubber tire	....	....	.1	.4	.1	.4
4-horse steel tire	[2] 1.5	6	19.2	76.8	16.3	65
Horses	1.5	.9	5.4	3.2	4.8	2.8
Bicycles	19	1.9	919.7	92	769.6	76.9
Automobiles	121.5	182.3	520.7	781.1	454.2	681.3
Total	2,107.5	4,622.6	4,585.8	8,024.2	4,172.8	7,457.3
Average tons per foot of roadway	....	92.45	....	160.49	....	149.15
Estimating 90 per cent of travel on middle 25 feet of roadway, average tons per foot	....	166.41	....	288.87	....	268.46
Teams trotting	1,439	....	2,134.6	....	2,018.7	....
Teams walking	526.5	....	1,005.4	....	925.6	....

[1] Sleds.

[2] Wagons.

TABLE 9.—*Detailed average travel records on Nicollet Avenue between Washington Avenue and Second Street during 1909.*

Classification of travel.	Averages.				Total average for the year.	
	For the first 2 observations when there was snow.		For the last 10 observations.			
	Number.	Tons.	Number.	Tons.	Number.	Tons.
Loaded:						
1-horse rubber tire	159.5	239.2	36.5	54.7	57	85.5
1-horse steel tire	111	166.5	541.2	811.3	468.5	703.9
2-horse rubber tire	245	1,102.7	52.7	237.6	84.7	381.8
2-horse steel tire	231.5	1,047.5	633.2	2,848.7	566.3	2,548.5
4-horse steel tire	1.5	12	33	264	27.7	222
Light:						
1-horse rubber tire	502.5	502.5	161.9	161.9	218.7	218.7
1-horse steel tire	295.5	295.5	702.6	702.6	634.7	634.7
2-horse rubber tire	276.5	691.5	58.4	146	94.7	237
2-horse steel tire	246.5	616	412.6	1,031.5	385	962.3
4-horse steel tire	1	4	23.6	94.4	19.8	79.2
Horses	4.5	2.7	7.8	4.7	7.3	4.4
Bicycles	6	.6	737.2	73.7	615.3	61.5
Automobiles	172.5	258.7	647.4	971	568.3	852.3
Total	2,253.5	4,939.8	4,048.1	7,623.2	3,748	7,175.9
Average tons per foot of roadway	....	98.79	....	152.46	....	143.52
Estimating 90 per cent of travel on middle 25 feet of roadway, average tons per foot	....	177.9	....	274.9	....	258.5
Teams trotting	351.3	....	989.3	....	882.4	....
Teams walking	1,719	....	1,666.5	....	1,674.7	....

TABLE 10.—*Detailed average travel records on Nicollet Avenue between Washington Avenue and Second Street during 1910.*

Classification of travel.	Averages.				Total average for the year.	
	For the first 2 observations when there was snow.		For the last 10 observations.			
	Number.	Tons.	Number.	Tons.	Number.	Tons.
Loaded:						
1-horse rubber tire	126	189	20.9	31.3	38.4	57.6
1-horse steel tire	70	105	351.7	527.6	304.8	457.2
2-horse rubber tire	224.5	1,010.25	36	162	67.4	303.3
2-horse steel tire	110	495	669.9	3,014.5	576.6	2,594.7
4-horse rubber tire	....	....	.1	.8	.1	.6
4-horse steel tire	....	....	39.4	315.2	32.8	262.7
Light:						
1-horse rubber tire	375	375	183.4	183.4	215.3	215.3
1-horse steel tire	124	124	865.5	865.5	742	742
2-horse rubber tire	246.5	616.25	113.3	283.3	135.5	338.8
2-horse steel tire	129.5	323.75	565.4	1,413.5	492.7	1,231.7
4-horse rubber tire	.5	2	.2	.8	.2	1
4-horse steel tire	1.5	6	31.9	127.6	26.8	107.2
Horses	4	2.4	4.7	2.8	4.6	2.7
Bicycles	1	.1	803.4	80.3	669.7	66.9
Automobiles	201	301.5	1,023.7	1,535.6	886.6	1,329.9
Total	1,613.5	3,550.25	4,709.5	8,544.21	4,193.5	7,711.6
Average tons per foot of roadway	....	71	....	170.88	....	154.23
Estimating 90 per cent of travel on middle 25 feet of roadway, average tons per foot	....	127.8	....	307.20	....	278
Teams trotting	1,220	....	1,842	....	1,739	....
Teams walking	187	....	1,035	....	894	....